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Visualizing Accessibility with GIS

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Introduction

As the environmental, social, and health costs of sprawling, automobile dependent development patterns become well understood, accessibility, or walkability, becomes a significant goal of planners, policy makers, and citizens. Our current planning environment is one of auto-mobility, which has the goal of reducing the cost per mile of travel within a metropolitan area. An auto-mobility approach may find success for a 15 minute commute that travels fifteen miles at speeds of sixty plus miles per hour – the cost per mile is relatively low in terms of time and delay. Similarly, an auto-mobility approach to regional travel would be considered a failure when congestion inhibits automobile travel from traveling at maximum speed limits; the cost per mile becomes quite high on account of time delays in traffic.

In contrast, an accessibility focus of development seeks to help people gain access to their destinations at a low cost per trip. In an accessibility-centered approach, popular places to visit cause increased numbers of people on sidewalks and in street intersections. These increases in turn tend to slow down the speeds of automobiles in the area. There is a tradeoff of mobility that favors the pedestrian rather than the automobile.

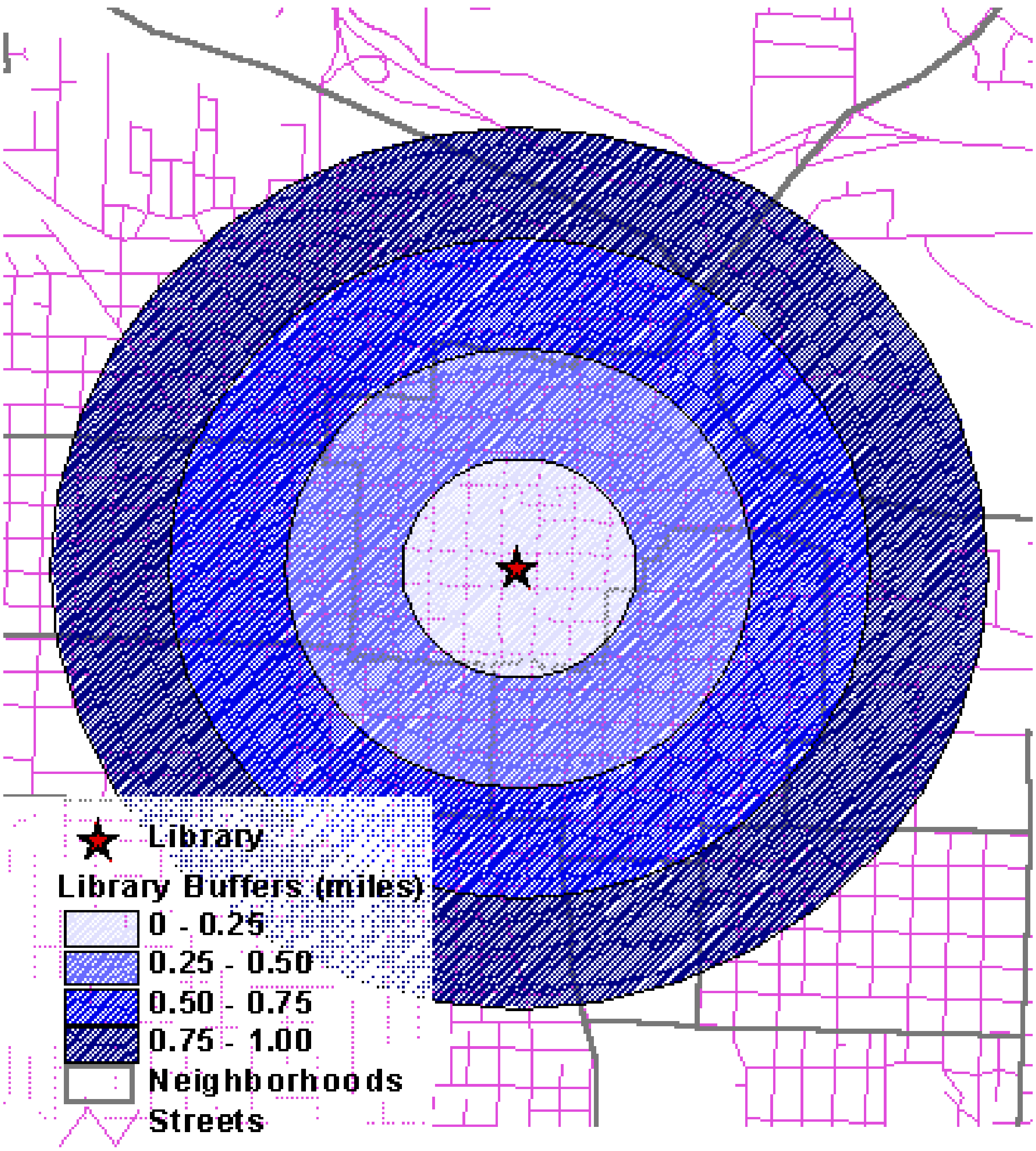
Developers and planners are increasingly incorporating such tradeoffs involving pedestrian accessibility into their visions and plans. They tend to base their decisions on a variety of principles, including increased quality of life, more active community interaction, environmental benefits of reduced automobile dependence, and congestion reduction. These principles are often characterized, in part at least, under a variety of terms: "New Urbanism," "Neotraditional Planning," "Pedestrian Pockets," "Transit Oriented Development," or "Nodal Development." The claimed or potential benefits of these schemes is beyond the scope of the current discussion. The focus here is on visualizing accessibility principles: to visualize is to clarify.

What are the various ways that one can visualize accessibility using Geographic Information

Systems (GIS)? This presentation uses the centralized area of Eugene, Oregon (USA) as the case study. Eugene has a centralized downtown with a gridded street network, has several old, established neighborhoods, and has some newer developments as well. Most of Eugene's topography is flat, except for portions of South Eugene, which ascends up some foothills. Eugene has clearly identified neighborhoods that are recognized by the City and are represented by elected neighborhood association presidents. Measuring accessibility at a neighborhood scale can be facilitated by these pre-existing boundaries of the neighborhoods.

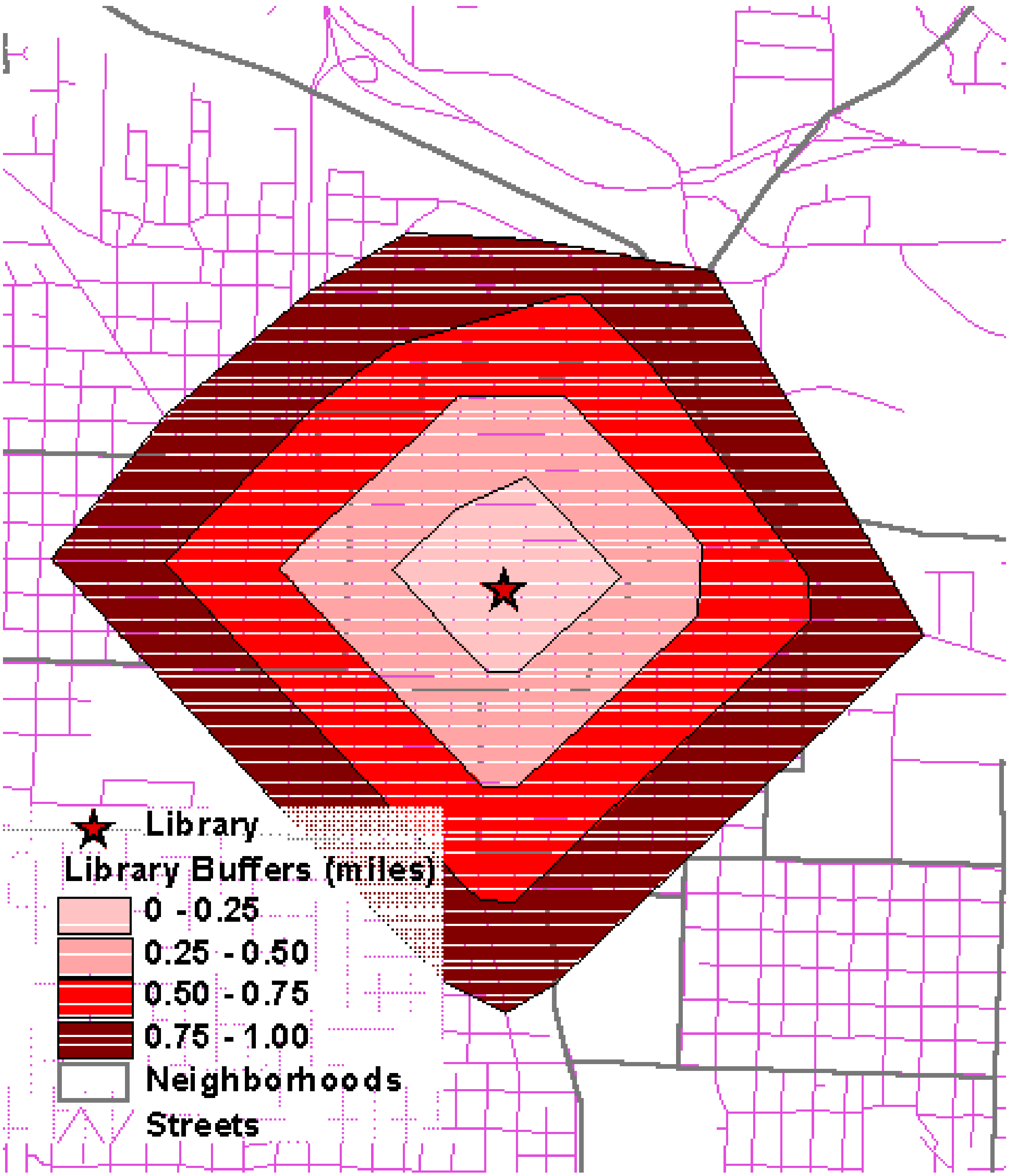
Accessibility through Buffering

Figure 1: 1/4 Mile Buffers as the Crow Flies Around Key Destination



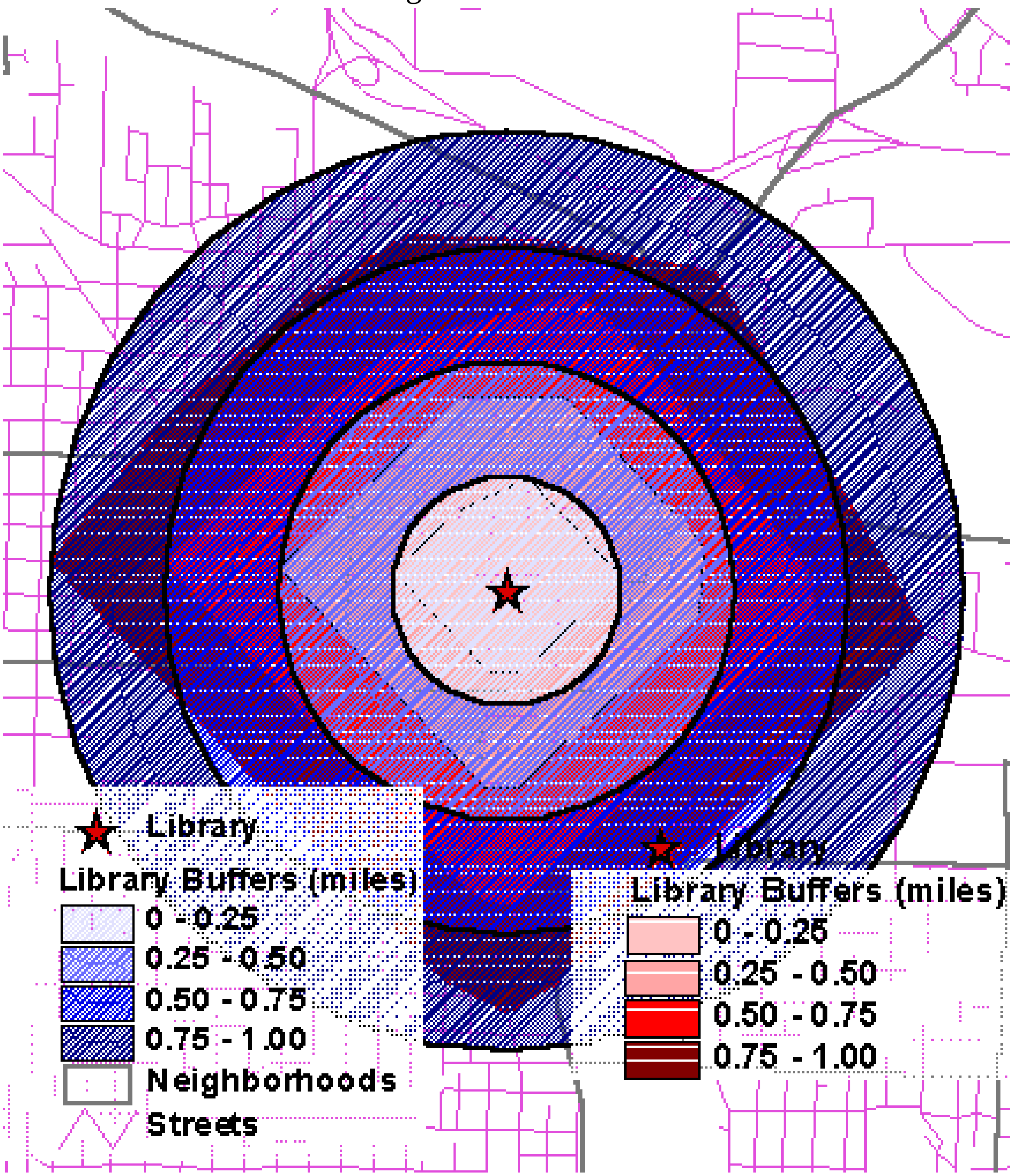
An easy way to visualize accessibility to a specific place is to use "buffer." Buffers target areas all of which are within a given distance of a point, line, or area. Thus, Figure 1 shows four buffers around the Library location. Buffering is a common GIS technique and can be used to quickly identify a geographic area that is considered accessible or walkable to a given location. Planners often consider a ¼ mile distance from a location as being the maximum distance that people are willing to walk to get to the destination they desire. Thus, Figure 1 shows ¼ mile rings of accessibility to a new downtown library that is being constructed in Eugene. The buffer rings (in Figure 1) are "as the crow flies", and do not take into account the actual paths that people may need to take to access the library. Thus, Figure 2 shows ¼ mile rings around the library based on the actual walking path of the street network (assuming that all streets have sidewalks and that there are no other walking-only paths). The diamond shaped buffer rings reflect the gridded street pattern of this part of Eugene.

Figure 2: 1/4 Mile Walking Buffers Around Key Destination



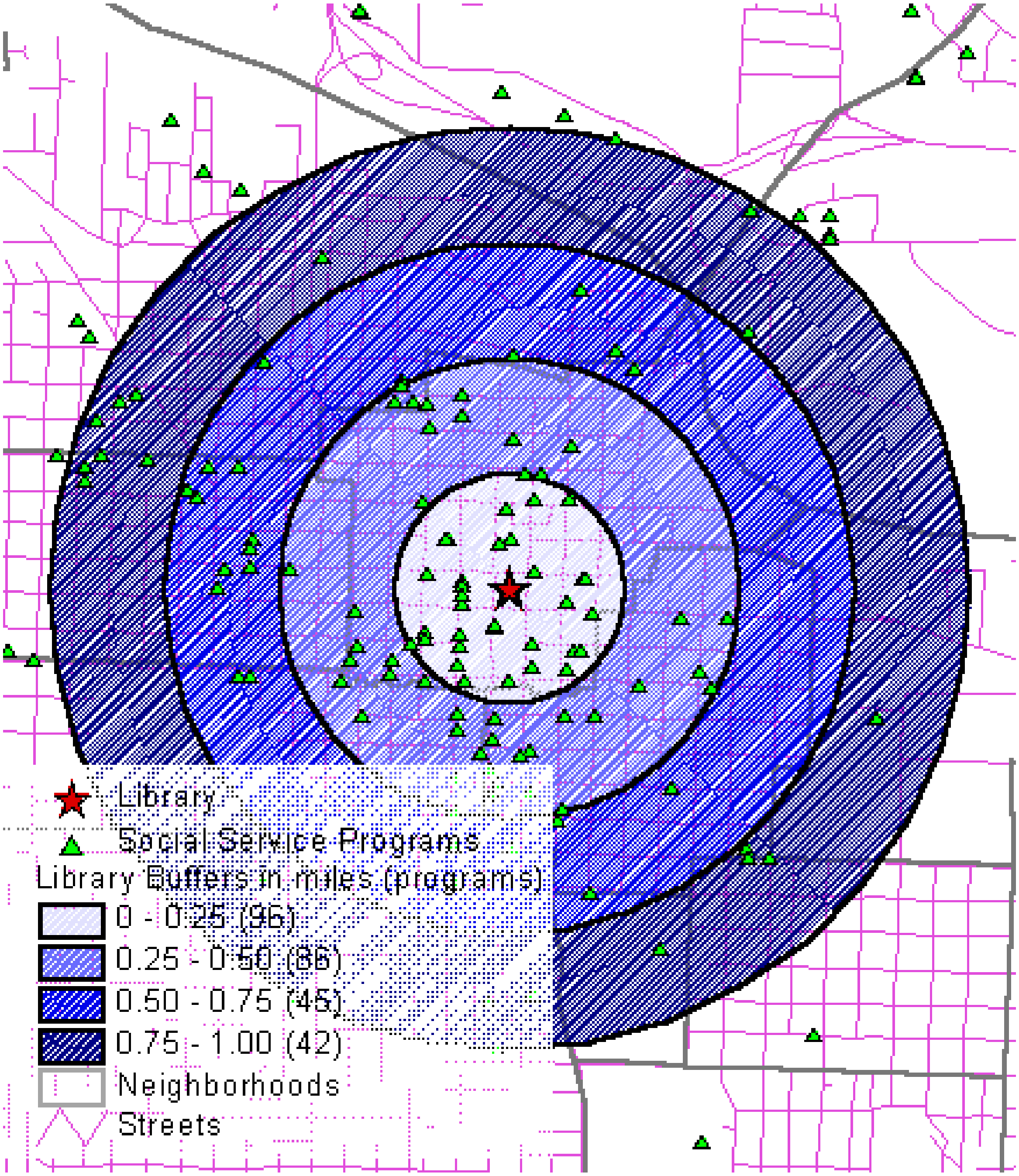
When Figures 1 and 2 are combined as Figure 3, the new Figure shows the overlap between the two different accessibility measurements. In this so-called "Ped Shed" of Figure 3, the ¼ mile buffer area of each technique can be compared by dividing the area of one by the area of the other to calculate a Ped Shed ratio [Rood, n.d.]. Different ratios imply areas that are more or less walkable.

Figure 3: Ped-Shed



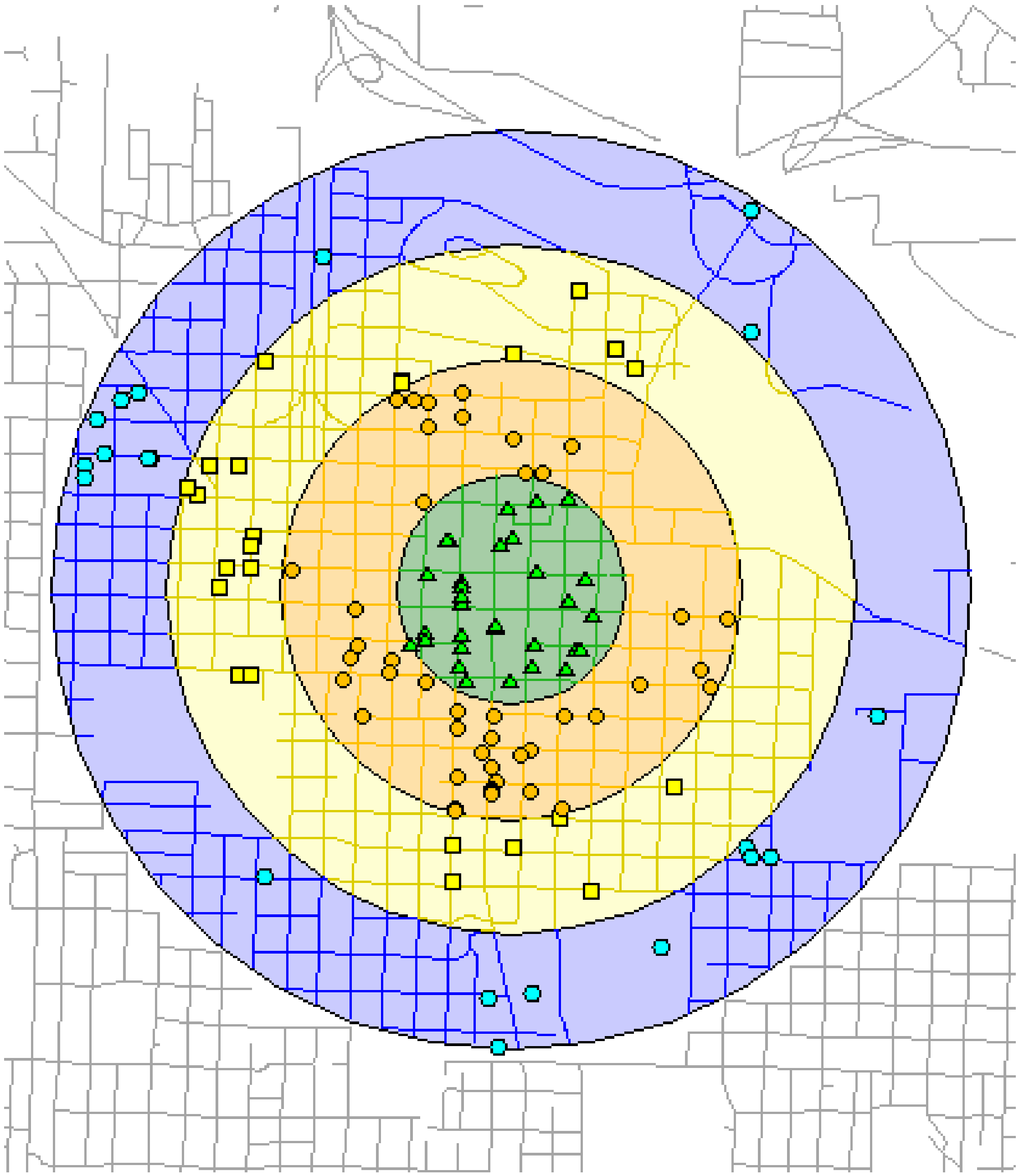
Additional aspects of urban life may also be identified within the walkable buffers. For example, planners at the library may wish to provide sensitive services to people with special needs for social services located near the library. Figure 4, plots the location of social services with the buffer rings to give the library a sense of the type of potential demand it may receive from any of a number of specialized populations.

Figure 4: Potential Social Service Patrons



While the image of Figure 4 is fairly intuitive and easy to read, additional visualization manipulations are possible to increase the clarity of the information being presented. Since the data underlying the image is spatial, data within each buffer can be individually selected and color coded based on its location. Figure 5 illustrates this approach by altering the color of variables (buffer, streets, and social services) based on geographic location. Thus, the visual representation of accessibility is enhanced and the capacity to distinguish or visually segregate the data based on geographical location is improved.

Figure 5: Color Coding Data by Distance



Visualization may be further enhanced by viewing the rings in three dimensions. In Figure 5, there is no discernable change in distance between each ¼ mile buffer and in many cases the line dividing each buffer distance is arbitrary in relation to the movement of people. Instead, tier the distances in a way that conveys the visual message that the geographical dividing lines are not arbitrary, but have real implications for the movement of people through space. Figures 6 and 7 represent the library and its buffers using three dimensional tiers. Color coding of the data within each tier enhances the visual effect.

Figure 6: 3D Tiers of Accessibility

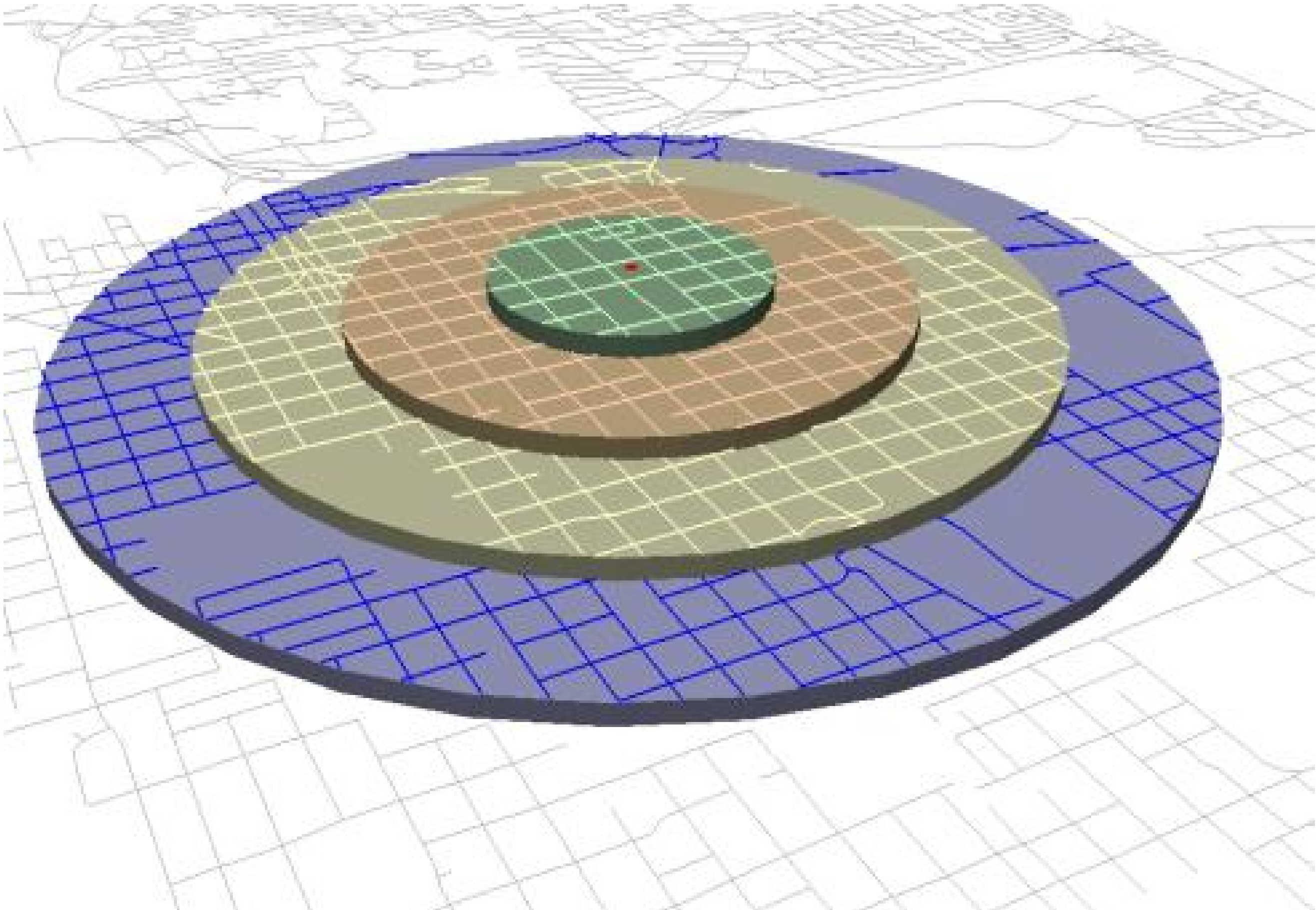
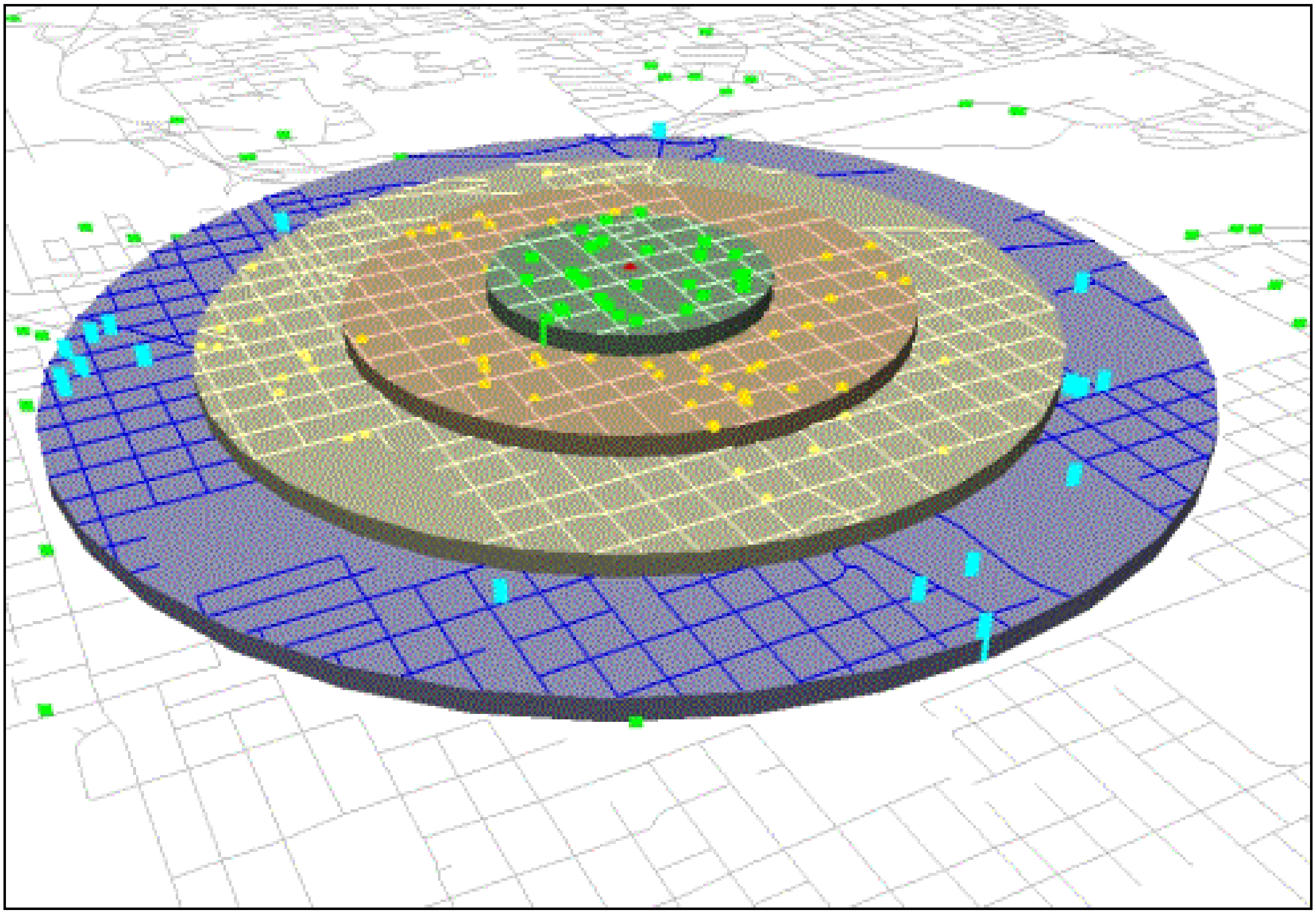


Figure 7: 3D Tiers of Accessibility with Social service Program Locations

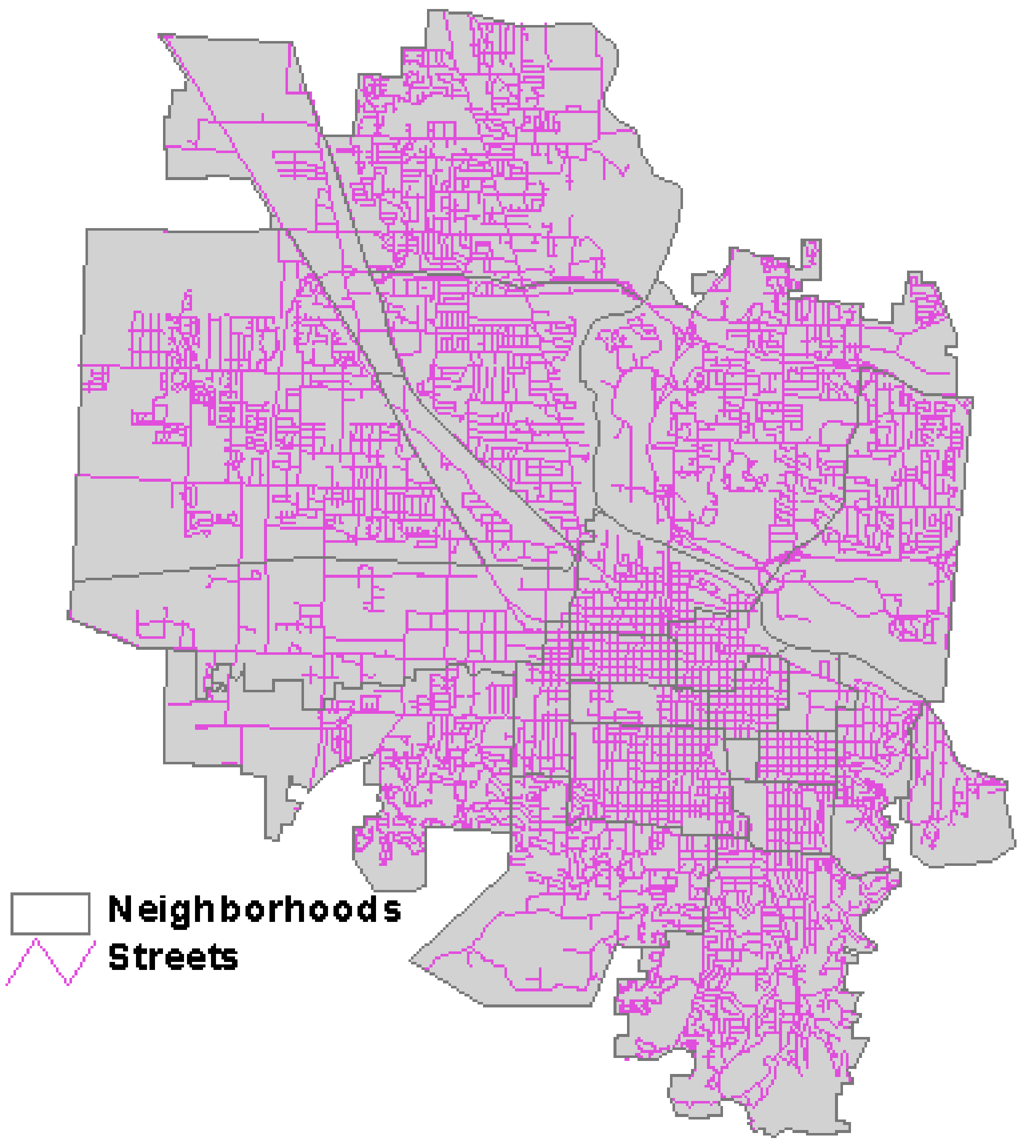


Accessibility through Intersection Density

The images above visualized accessibility in terms of the distance to a specific place. One might, instead, look across a landscape to ascertain which sub-areas are characterized by potentially more accessible movement patterns. Some areas within a region may have street networks (and therefore sidewalk networks) that are more conducive to walkability. Thus, accessibility may be visualized by investigating different patterns of street networks. Within the development schemes mentioned at the outset (New Urbanism, Nodal Development, and so forth), one idea is that street patterns that are based on a grid are more accessible than non-grid patterns. Within a gridded street network, there are redundant paths that walkers can use to access the same destination. This increase in path choice can be represented by areas with numerous street intersections and thus relatively great accessibility. One way to view this idea is to consider the difference in numbers of intersections and accessibility between a downtown street network grid suburban development with many cul-de-sacs. Regions with higher concentrations of intersections are regions with higher potentials for accessibility. The following series of images visualizes this characterization of accessibility.

Figure 8 shows the street pattern within the central Eugene Neighborhoods. The downtown core is located at about the center of the map. From only this simple map of one layer, it is visually possible to get a sense of which areas in Eugene are more walkable.

Figure 8: Eugene Street Network



Although one can get a general sense of accessible places by simply viewing the street layer, it is possible to perform a series of calculations based on the location and density of intersections (or cul-de-sacs). By viewing the concentration of intersections, one can get a better grasp of the connectivity of the street network across space. Figure 9 and Figure 10 visualize the street network based on the location of intersections and cul-de-sacs (or dead-ends).

Figure 9: Intersection and Dead End Points

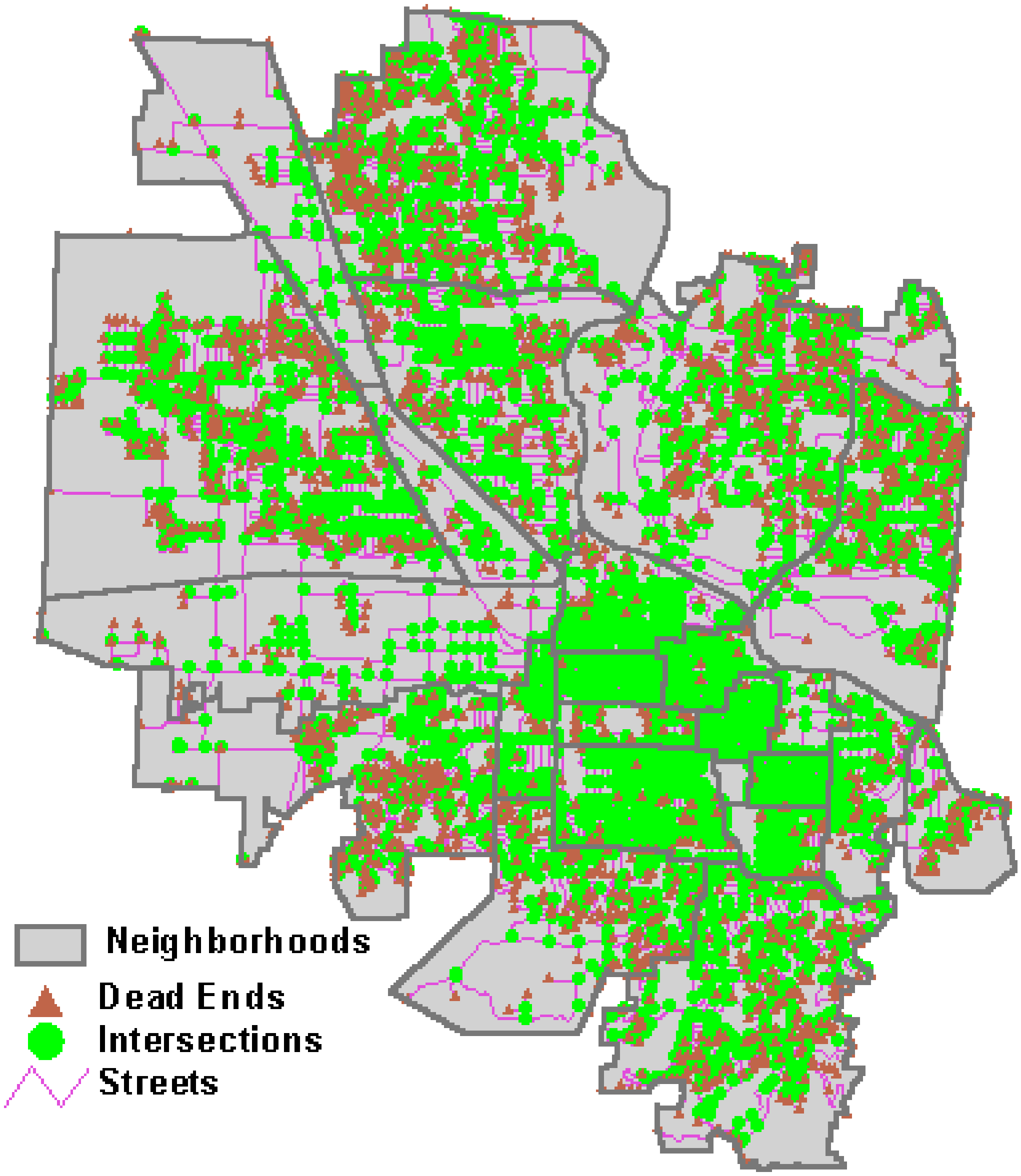
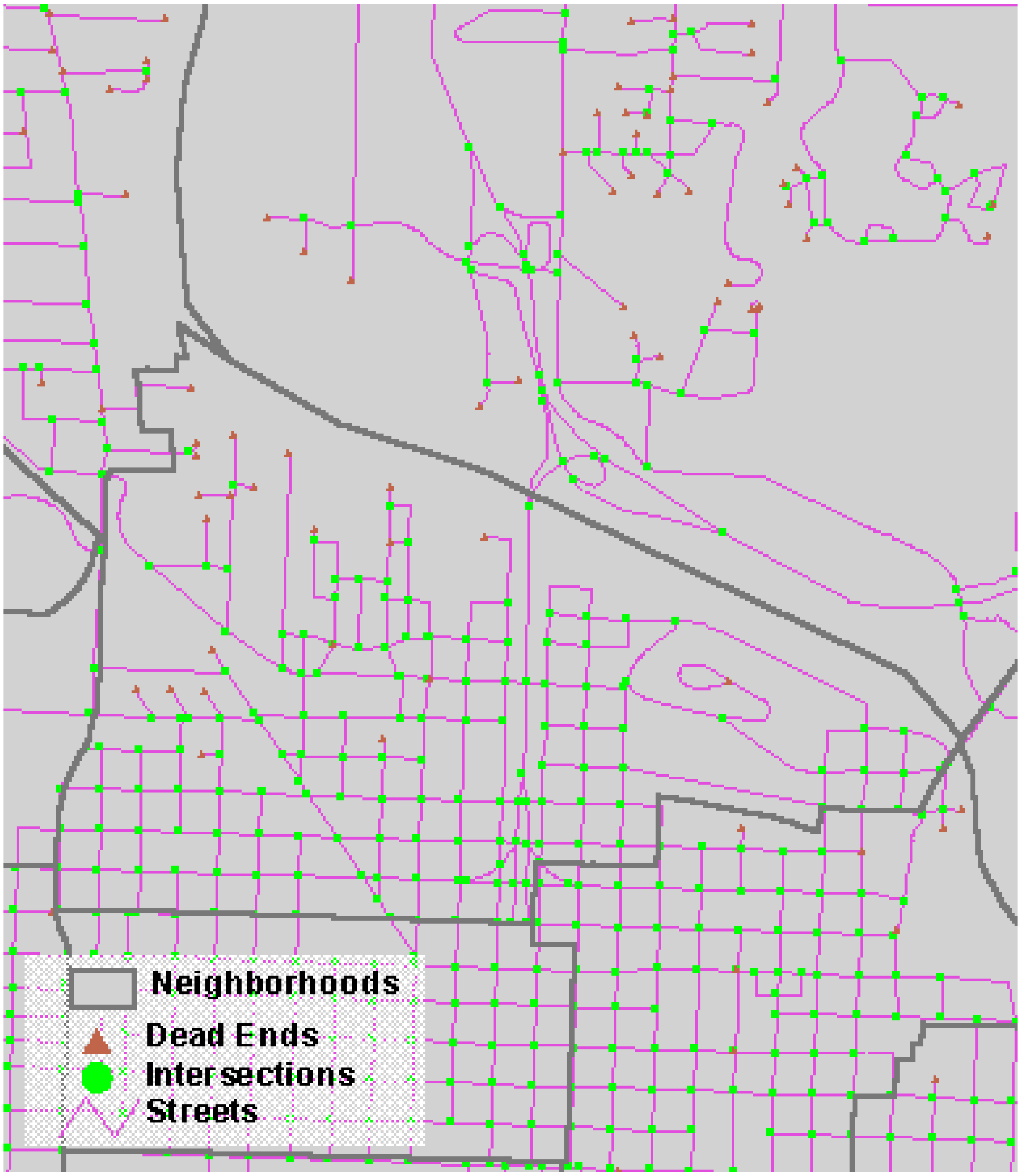


Figure 10: Close-up of Intersection and Dead End Points



Visualizing concentrations of intersections is helpful, but it may be that one would want to characterize the different neighborhoods in Eugene based on the density of intersections within the neighborhoods. Neighborhoods with higher intersection density (intersections per square mile) might be considered as more accessible than those neighborhoods with lower intersection densities. Figure 11 visualizes the aggregation of intersections within each neighborhood divided by the total area of each neighborhood to calculate a relative intersection density figure. Figure 12 visualizes a similar calculation, but is based on the concentration of cul-de-sacs – areas that can be classified as having low accessibility.

In Figure 11 there is a clear pattern of higher accessibility in the centralized area of Eugene, the location with the tightest grid pattern of development. This is the oldest developed portion of Eugene and was developed before the predominance of automobiles. The lighter colored neighborhoods out to the west are areas where more industrial development has occurred and the street network, and thus the density of intersections, follows a much less dense pattern. In Figure 12, the areas that have a more characteristic suburban style of development are clearly visualized.

The southern portion is hilly and the street network tends to transect the mountains in long straight swaths with few intersecting streets. The dark area to the north in Figure 12 is an area more recently developed and follows a street pattern much more characteristic of the post-war suburban approach.

Figure 11: Street Intersection Density by Neighborhood

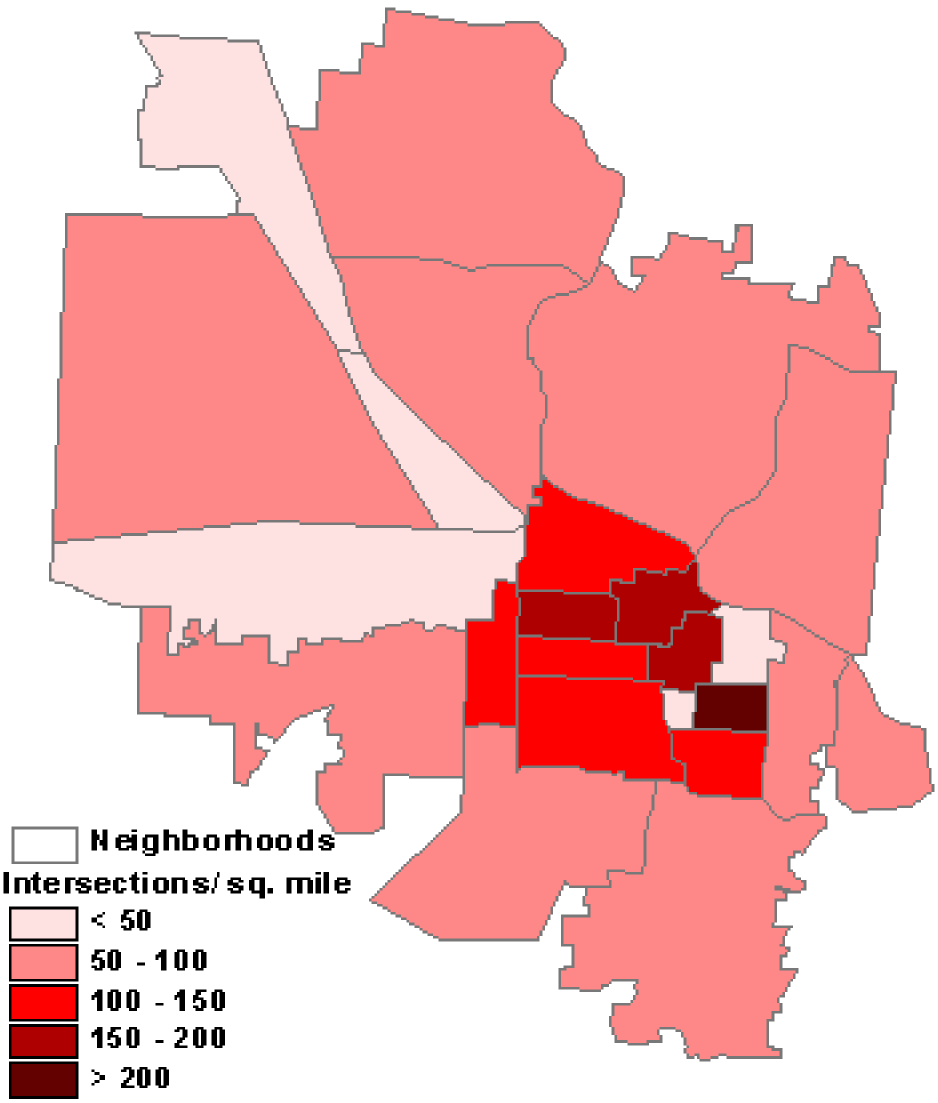
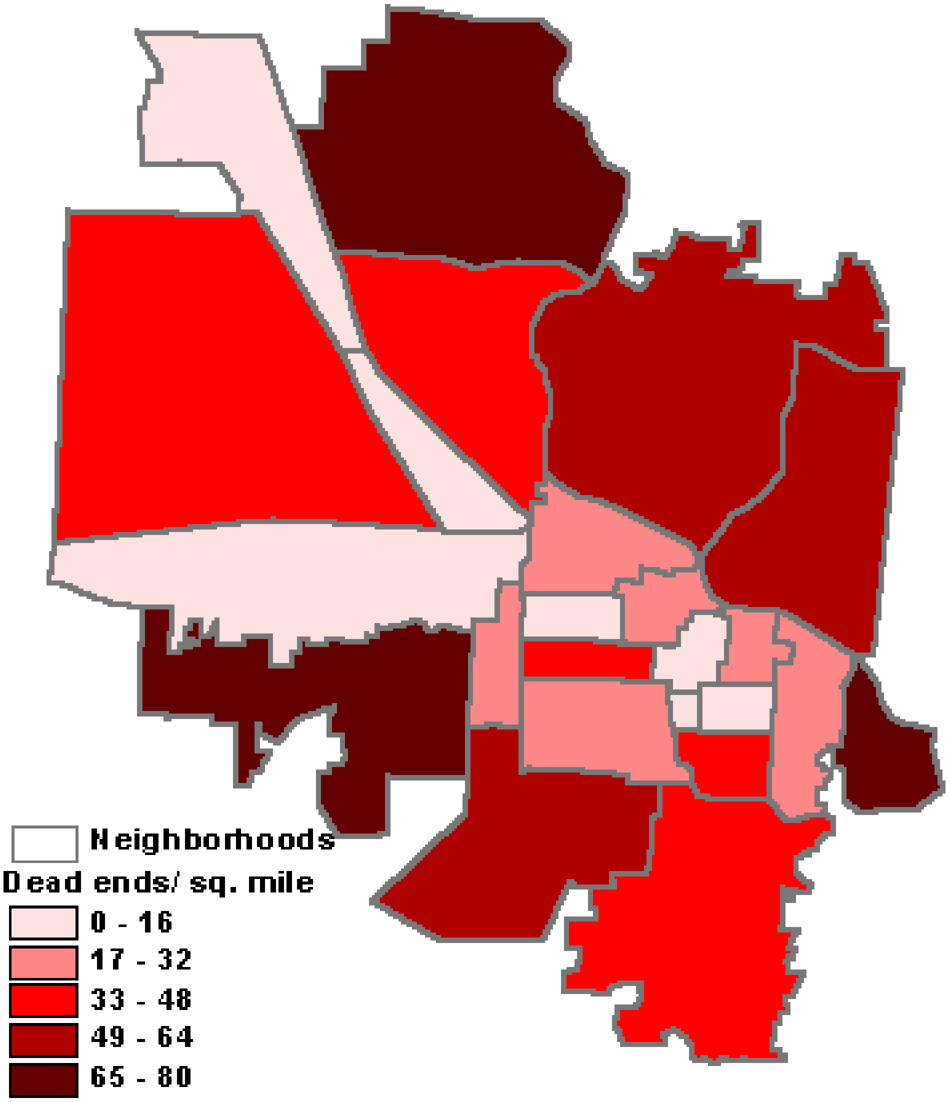
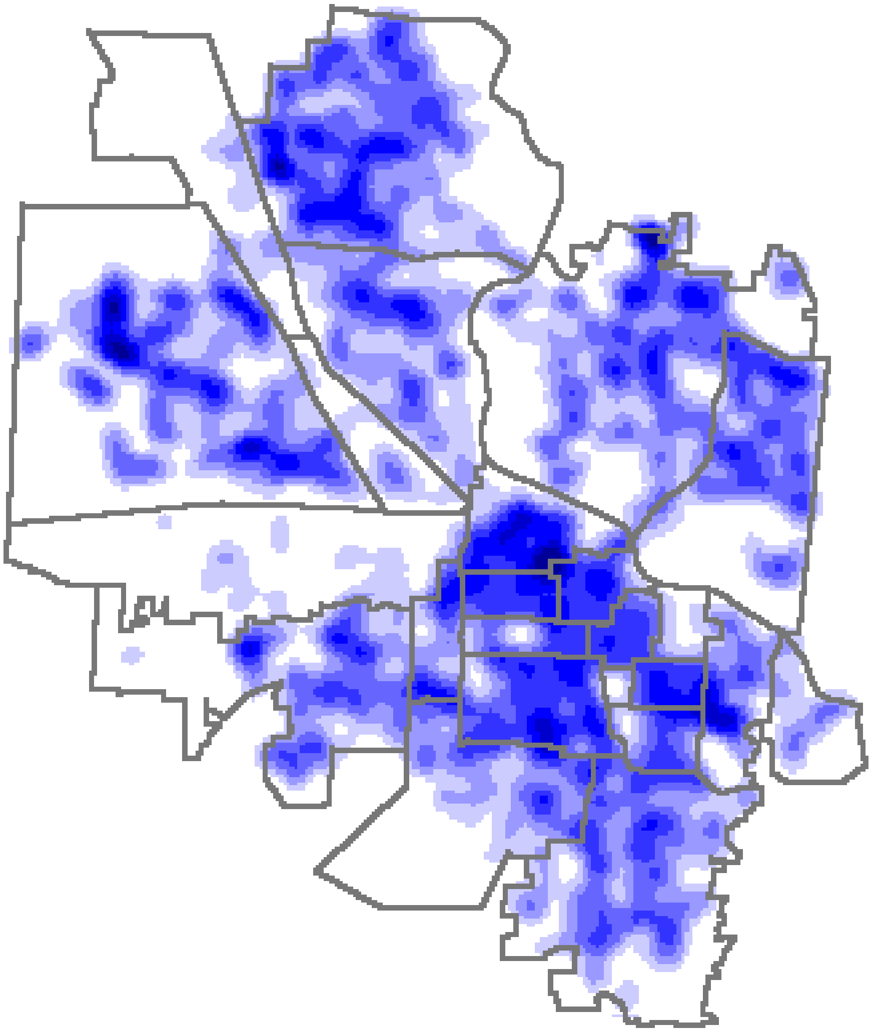


Figure 12: Dead End Density by Neighborhood



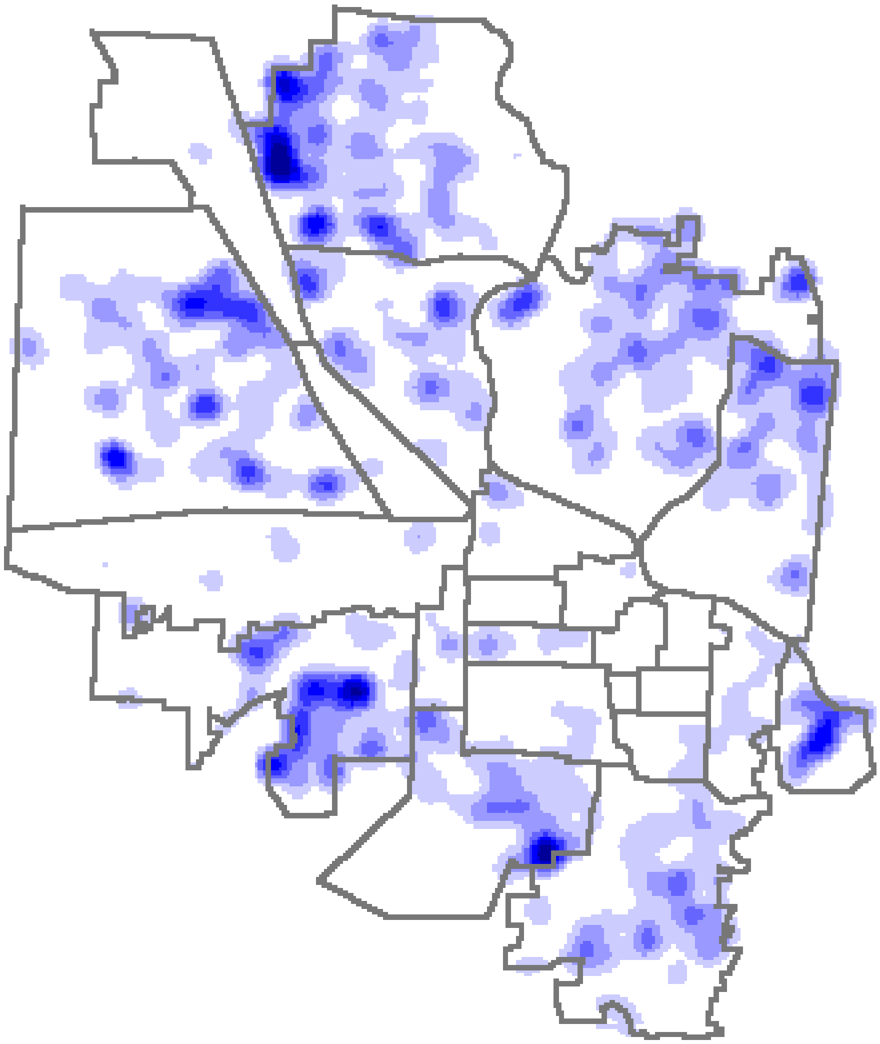
The figures above aggregate intersections to specific Eugene neighborhoods, which allows one to visualize accessibility on a neighborhood by neighborhood basis. Aggregating intersections to these pre-defined boundaries, however, is a bit artificial in nature. Alternatively, as shown in Figure 13, intersection density can be calculated by exact location in space. The intersection density of each spatial location can be calculated and then visualized based on the number of intersections that surround it. By transforming the vector data above to raster data (cells), a computation of the intersections within a ¼ mile of each cell can be calculated and displayed. Individual cells that are centrally located in relation to many intersections will appear in darker colors. Thus, regions of high intersection density can be visualized independent of the arbitrary borders of neighborhoods (or city boundaries, census tracts, and so forth). The neighborhood boundaries in Figure 13 are displayed, however, to give reference to the intersection density visualization.

Figure 13: Intersection Density by Point Location



The same type of calculation and visualization can be conducted on the density of dead-end streets or cul-de-sacs as shown in Figure 14.

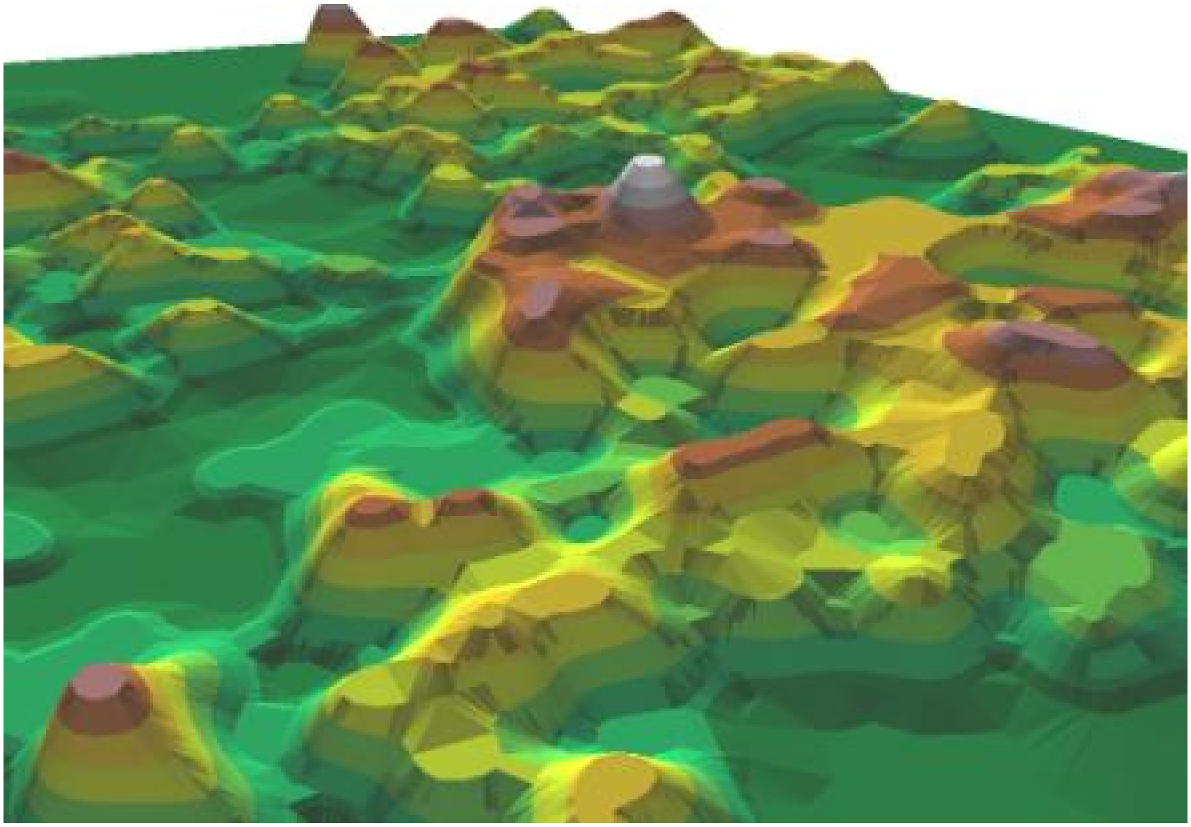
Figure 14: Dead End Density by Point Location



Figures 13 and 14 suggest locations where development has occurred in a way that is highly walkable and highly unwalkable.

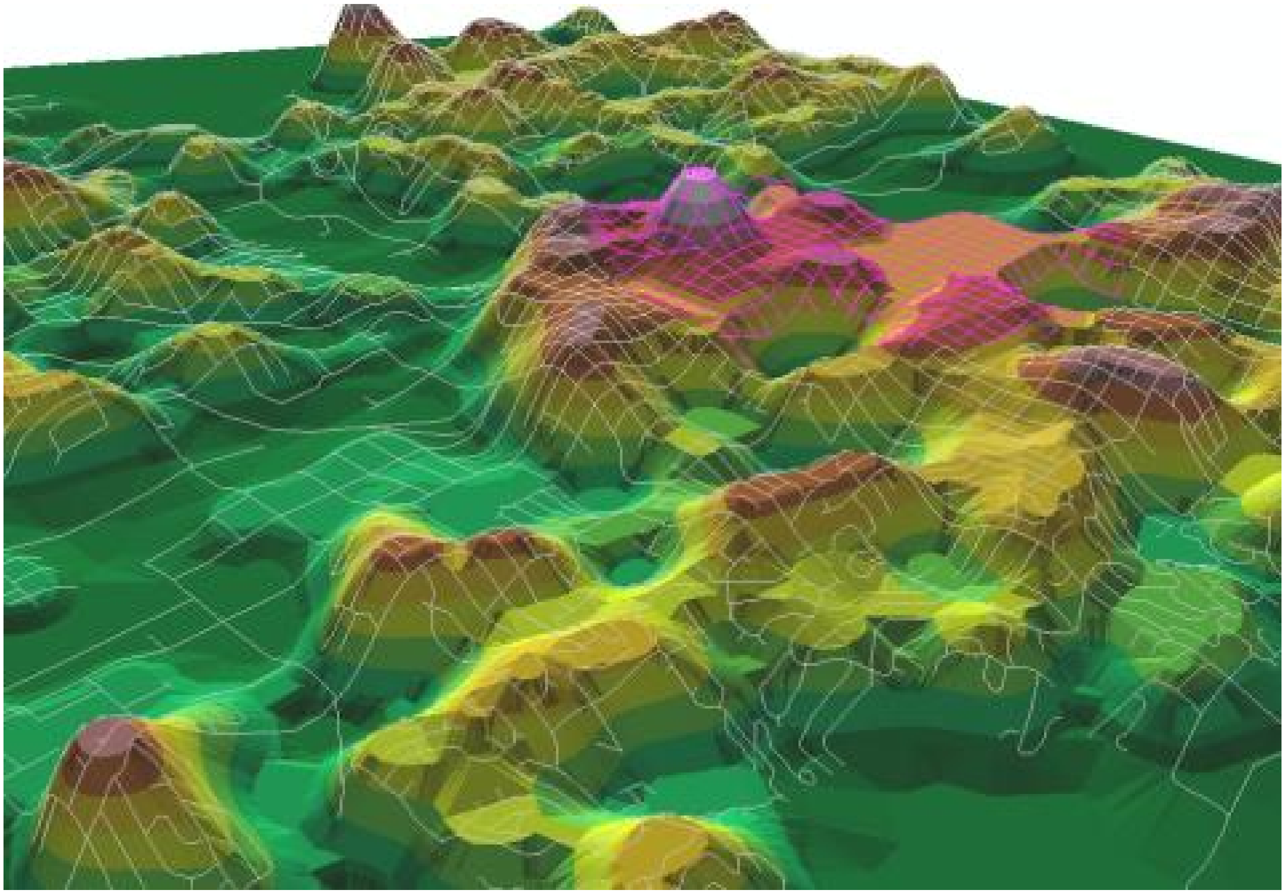
Accessibility using these raster-based calculations can also be viewed in three dimensions, using density of intersections in space, rather than actual elevation of land features, to create the topographic effect. Figure 15 visualizes the central Eugene area using this strategy, with mountain peaks representing areas of highest accessibility (concentration of intersections) and low areas representing places of low accessibility.

Figure 15: Elevation by Intersection



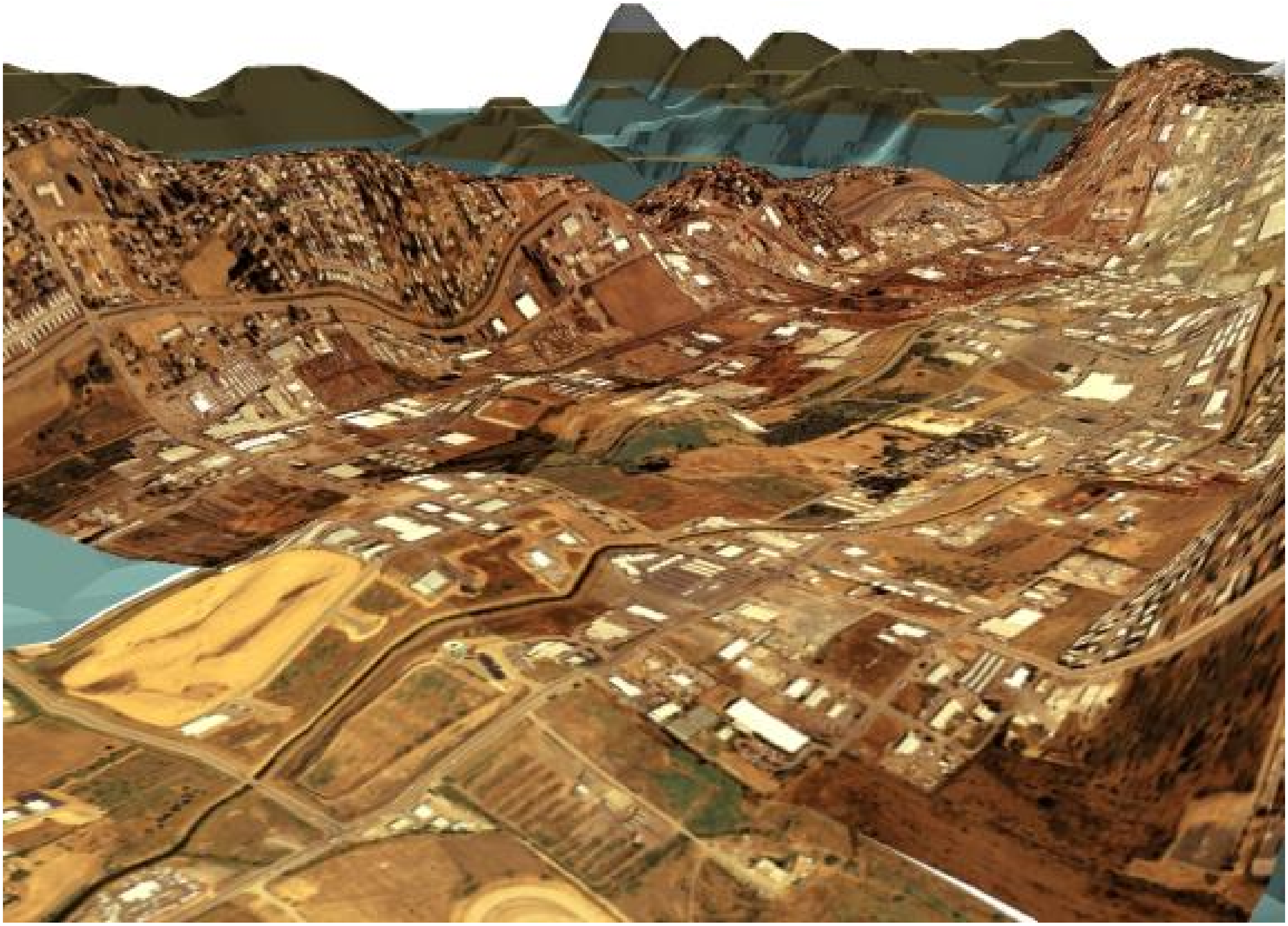
The three dimensional approach can be further augmented by overlaying the street network on top of the intersection topography to help visualize the concept of accessibility. Figure 16 illustrates this combination with streets within ¼ mile of the library highlighted in pink. That Figure also shows that the location of the new library is on the most accessible land of downtown Eugene. While not shown explicitly, the center of the pink streets (the location of the library) is just to the right of the tallest mountain peak (the location of the highest intersection density).

Figure 16: Intersection Elevation and Streets



Finally, aerial photographs can be draped on top of this new intersection topology to allow one to visualize the actual development of an area in relation to intersection density. Figure 17 visualizes accessibility using color aerial photos and the intersection-based topography. Some areas on the image below do not have aerial photos displayed in order to reveal the underlying connectivity as illustrated in Figures 15 and 16.

Figure 17: Intersection Elevation with Aerial Photos



In Figure 17, then, one can visualize the landscape of a city in a new way based on accessibility. Areas of high accessibility can be represented as mountain peaks (or alternatively as flat spaces) and the photographs of actual development can be viewed with this new underlying elevation. A policy connection, as well as a visual connection, might then be made between development patterns and accessibility.

Rood, T. (n.d.). Ped Sheds. Congress for a New Urbanism, Internet: http://www.cnu.org/cnu_reports/CNU_Ped_Sheds.pdf